APPENDIX 44

MALCOLM PIRNIE

Technical Memorandum

Date:	October 19, 2010
To:	Virginia Association of Municipal Wastewater Agencies
From:	Clifton F. Bell, Malcolm Pirnie, Inc.
Re:	Screening-Level Analysis of Nutrient and Sediment Control Options: York River Basin Demonstration

ABSTRACT

A screening-level analysis was performed to explore the sensitivity of costs, cost-effectiveness, and other ancillary environmental benefits to the nutrient and sediment reduction practices selected for implementation. The analysis applied the *BMP Benefit Planner* version 1.1 to the York River basin. The default implementation scenario was based on USEPA's draft (September 2010) TMDL scenario, and the alternative scenario was constructed to target more cost-effective nonpoint source practices and maintain regulatory stability for point sources. Results demonstrated that the alternative scenario was only 50% as costly as the default scenario, had 20% lower greenhouse gas emissions, and 19% higher rates of carbon sequestration. The alternative scenario also had higher ratings for various ancillary environmental benefit categories, including wildlife habitat and in-stream habitat protection.

INTRODUCTION

It is well established that best management practices (BMPs) intended to reduce nutrient and sediment loads have other environmental effects that can be positive or negative with regard to ecosystem services and overall sustainability. Some BMPs provide net benefits to greenhouse gas (GHG) emissions, carbon sequestration, wildlife habitat, *etc.* whereas other practices are neutral or even cause net detriments in these regards. Similarly, BMPs vary greatly in their cost-effectiveness; *i.e.*, pollutant mass reduced per dollar invested.

The purpose of this memo is to present a screening-level demonstration of how cost-effectiveness and ancillary environmental benefits of a watershed implementation plan can be improved by careful selection of the type and amount of BMPs. The York River Basin in Virginia was used as a case study, with the default BMP implementation scenario approximately represented by the watershed model input deck associated with USEPA's September 2010 draft total maximum daily load (TMDL) (USEPA, 2010). The *BMP Benefit Planner* version 1.1 (Malcolm Pirnie, 2010) was used explore how the overall costs and benefits of the default scenario might be improved by targeting cost-effective practices.

METHODS

The *BMP Benefit Planner* is a Microsoft® Excel®-based model for comparing watershed implementation plans with respect to environmental sustainability and cost-effectiveness. The user input is the extent (acreage, linear feet, million gallons per day, *etc.*) of various management practices for reducing nutrient and/or sediment loads, including wastewater treatment plant nutrient removal upgrades, forestry practices, agricultural practices, and urban stormwater retrofits. It estimates the costs, greenhouse gas emissions, and carbon sequestration associated with these practices. The *BMP Benefit Planner* utilizes many default BMP efficiency and cost factors derived from USEPA references and the scientific literature, as documented by Malcolm Pirnie (2010).

The *BMP Benefit Planner* uses a semi-quantitative approach to compare scenarios with respect to other ecosystem services such as wildlife habitat, flood hazard risk, and public health protection. Ancillary benefit scores of individual practices reflect the effectiveness of each practice to specific benefit categories, and the extent of that practice relative to the watershed size. Ancillary benefit scores for all BMPs are summed to provide a total score for each ancillary benefit category for each scenario. Due to the semi-quantitative nature of this method, results are used only to compare scenarios rather than to determine the absolute value of ecosystem services for an individual scenario.

Default (Draft TMDL) Scenario

Information on the extent of nonpoint source BMPs for the draft TMDL scenario was obtained from the Chesapeake Bay Program ftp site (ftp://ftp.chesapeakebay.net/Modeling/phase5/), and specifically from the file entitled "bmpacres_2010EPA19N091710.csv". The land use breakdown of the York River Basin was obtained from the spreadsheet entitled "P53_Loads_Acres_2010EPA19N091710.xls" (Table 1). Acreages of land under non-enhanced nutrient management were determined directly from the land-use categories.

The Phase 5.3 watershed model (WSM5.3) includes more BMP varieties than are included in the *BMP Benefit Planner* version 1.1. For the purposes of this screening-level exercise, BMP acreages of the WSM5.3 were aggregated into BMP categories of the *BMP Benefit Planner* as shown in Attachment A. The final *BMP Benefit Planner* input sheets are compiled in Attachment B.

Major municipal point sources were categorized by design flow and the effluent concentration basis (TN = 4 mg/L; TP = 0.3 mg/L) of the "backstop" wasteload allocations of USEPA draft TMDL, and the summed design flows for each flow category were entered into the *BMP Benefit Planner*. Because industrial point source flows were not modified between the default and alternative scenarios, they were not explicitly considered in this exercise.

TABLE 2
Land Use/Cover of the York River Basin

Land Use	Acres	Percent
Open water	27,507	1.4%
Forest (not inc. added forest buffers)	1,573,805	80.1%
Hay/Pasture	161,114	8.2%
Cropland	115,923	5.9%
High intensity manure/CAFO	1,965	0.1%
Ultraurban	9,824	0.5%
Mixed Urban/Suburban	76,627	3.9%
TOTAL	**1,966,765**	**100%**

Alternative Scenario

The alternative scenario was constructed from the default scenario. Major municipal point sources were returned to their existing load allocations based on Virginia's general watershed permit registration list (9 VAC 25-820-70), as a means to provide regulatory stability and provide capacity for future "smart" growth. Because urban stormwater retrofits are among the least cost-effective means to reduce nutrients (Malcolm Pirnie, 2010), the acreages of urban stormwater retrofits were reduced by 50% relative to the default TMDL scenario. The acreages of the remaining BMPs—primarily agricultural practices such as nutrient management, cover crops, conservation tillage, and animal waste management—were increased by 20%. The final acreages of BMPs for both the default and alternative implementation scenarios are provided in Table 2.

TABLE 2
Implementation Rates for the Default and Alternative Scenarios

Practice	Units	Default Scenario	Alternative Scenario	Difference
Municipal WWTP upgrades	mg/L N	18.7 reduced to 4	18.7 reduced to 6	-14%
	mg/L P	2.5 reduced to 0.3	2.5 reduced to 0.7	-18%
Nutrient management plans	acres	80,361	96,433	+20%
Enhanced nut. management plans	acres	137,175	164,610	+20%
Conservation tillage	acres	95,017	114,020	+20%
Cover crops	acres	29,062	34,875	+20%
CAFO-Animal waste management	acres	568	681	+20%
Grazing land management	acres	36,793	44,152	+20%
Riparian buffers – forested (100 ft)	ft	3,032,212	3,638,654	+20%
Riparian buffers – grass (100 ft)	ft	642,728	771,274	+20%
Wetland creation/restoration	acres	882	1,059	+20%
Stormwater retrofits-pervious	acres	24,451	12,225	-50%
Stormwater retrofits-impervious	acres	4,843	2,421	-50%
Stormwater retrofits-ultraurban	acres	12,578	6,289	-50%

The *BMP Benefit Planner* is not a watershed loading or water quality model, and would normally be used in combination with a separate model that quantifies water quality/loading benefits. However, the model includes a simple load calculator based on land use-specific loading factors and default BMP efficiencies (Malcolm Pirnie, 2010), primarily intended for scoping. The load calculator was used for this exercise to ensure that the default and alternative BMP implementation scenarios provided approximately the same level of loading reduction.

RESULTS AND DISCUSSION

The load reductions predicted by the *BMP Benefit Planner*'s load calculator for the default (draft TMDL) and alternative scenarios are presented in Table 3. Although these values are only rudimentary estimates, they are useful for demonstrating that the alternative scenario would accomplish approximately the same or slightly higher levels of nutrient and sediment load reduction, compared to the default scenario. Because the alternative scenario has more WWTP capacity to handle smart growth and prevent septic system sprawl, it might actually have a higher differential in the long-term reduction in nitrogen loads than indicated in Table 3.

TABLE 3
Pollutant Reduction Rates for the Default and Alternative Scenarios

Scenario	TN Load Reduction	TP Load Reduction	TSS Load Reduction
Default	31%	42%	7%
Alternative	33%	43%	9%

Table 4 summarizes the BMP Benefit Planner's comparison of the default and alternative implementation scenarios for the York River Basin. The alternative scenario was estimated to have a total capital, O&M, and annualized cost that is only about 50% of the cost of the default (draft TMDL) scenario. The huge cost reduction was driven primarily by the reduction in stormwater retrofit costs, but also by a significant reduction in WWTP capital and O&M costs. Because the two scenarios are estimated to achieve similar pollutant load reductions, the alternative scenario is also about twice as cost-effective (expressed in dollar spent per lb pollutant reduced) as the default scenario. Costs and cost-effectiveness of individual practices are summarized in Attachment C.

Both the default and alternative scenarios were predicted to cause a net reduction in GHG emissions, and so the GHG emissions are expressed as negative values for both scenarios. However, the alternative scenario was predicted to have much greater reduction (-712%) in emissions of greenhouse gases than the default scenario, primarily due to fewer emissions from wastewater treatment plants and more reductions from land under nutrient management. It was also predicted to have approximately 20% higher carbon sequestration, primarily due to the increases in riparian buffers, cover crops, conservation tillage, and rotational grazing.

The alternative scenario had slightly higher scores in all ancillary benefit categories including wildlife habitat, instream habitat, aesthetics, public health, flood hazard mitigation, and baseflow protection. These higher scores were caused by increased acreages of landscape-enhancing practices such as conservation tillage, riparian buffers, and cover crops. The reductions in WWTP upgrades and stormwater retrofits did not greatly affect the ancillary benefit scores because these practices either do not have high ratings for such benefits or affect only a small proportion of the landscape under the proposed acreages.

TABLE 4
Summary BMP Benefit Planner Results:
Comparison of Scenarios for the York River Basin

Benefit Category	Units	Default Scenario	Alternative Scenario	Difference
Costs				
Capital Cost	Pound $	$2,026,468,409	$1,027,823,507	-49%
O&M Cost	$/yr	$62,579,481	$30,577,153	-51%
Annualized Total Cost	$/yr	$228,443,135	$116,957,873	-49%
Greenhouse Gases				
GHG Emissions	Mg CO2e/yr	-2.29E+03	-1.86E+04	-712%
Carbon Sequestration Rate	Mg CO2e/yr	8.14E+04	9.74E+04	+20
Lifetime C Seques. Potential	Mg CO2e	7.34E+06	8.75E+06	+19
Load Reduction				
Cost per lb N Reduced	$/lb N/yr	$53	$25	-52%
Cost per lb P Reduced	$/lb P/yr	$342	$170	-50%
Cost per lb Sed. Reduced	$/ton/yr	$4,430	$1,994	-55%
Ancillary Benefit Ratings				
Wildlife habitat	--	3.2	3.5	
In-stream (aquatic) habitat	--	7.1	7.3	
Aesthetics	--	2.9	2.9	
Public health	--	4.3	4.7	
Flood hazard mitigation	--	7.5	8.0	
Baseflow protection	--	5.1	5.6	

CONCLUSIONS

This screening-level exercise demonstrates that the overall cost, cost-effectiveness, and environmental benefit of a watershed implementation plan is very sensitive to the mix of practices selected. Total scenario costs tend to be controlled by costly urban stormwater retrofits that achieve only small pollutant reductions at the watershed scale. Implementation scenarios that substitute (or trade) such practices for more widespread landscape-enhancing practices can achieve significantly higher environmental benefits at much lower costs. Similarly, the correct mix of point and nonpoint source practices can preserve regulatory stability for wastewater treatment plants and preserve treatment capacity for future "smart" growth.

REFERENCES

Malcolm Pirnie. 2010. Best Management Practice Benefit Planner Version 1.1—Technical Documentation and User's Guide. 89 p.

U.S. Environmental Protection Agency—Region 3. 2010. Draft Chesapeake Bay Total Maximum Daily Load. EPA-R03-OW-2010-0736-0026.

ATTACHMENT A
Aggregation of WSM BMP Categories into BMP Benefit Planner BMP Categories

BMP Category Watershed Model Phase 5.3	Area Acres	BMP Category BMP Benefit Planner version 1.1
AWMSLivestock_afo	462	Animal Waste Management
BarnRunoffCont_afo	292	Mixed-Land Use SW Retrofits - Pervious
ComCovCropEDW_hom	25	N/A
ComCovCropEDW_hwm	54	N/A
ComCovCropEDW_lwm	482	N/A
ComCovCropEDW_nhi	1,019	N/A
ComCovCropEDW_nho	471	N/A
ComCovCropEDW_nlo	9,159	N/A
ConPlan_alf	205	NMPs
ConPlan_hom	218	NMPs
ConPlan_hwm	472	NMPs
ConPlan_hyw	2,559	NMPs
ConPlan_lwm	4,240	NMPs
ConPlan_nal	3,902	NMPs
ConPlan_nhi	8,964	NMPs
ConPlan_nho	4,142	NMPs
ConPlan_nhy	48,624	NMPs
ConPlan_nlo	80,568	NMPs
ConPlan_npa	56,318	NMPs
ConPlan_pas	2,920	NMPs
CoverCropEDW_hom	41	Cover Crops
CoverCropEDW_hwm	89	Cover Crops
CoverCropEDW_lwm	803	Cover Crops
CoverCropEDW_nhi	1,698	Cover Crops
CoverCropEDW_nho	785	Cover Crops
CoverCropEDW_nlo	15,265	Cover Crops
CoverCropSDW_hom	23	Cover Crops
CoverCropSDW_hwm	50	Cover Crops
CoverCropSDW_lwm	446	Cover Crops
CoverCropSDW_nhi	944	Cover Crops
CoverCropSDW_nho	436	Cover Crops
CoverCropSDW_nlo	8,481	Cover Crops
DecisionAg_nhi	7,524	NMPs
DecisionAg_nlo	9,196	NMPs
DryPonds_imh	389	Mixed-Land Use SW Retrofits - Impervious

BMP Category Watershed Model Phase 5.3	Area Acres	BMP Category BMP Benefit Planner version 1.1
DryPonds_iml	397	Mixed-Land Use SW Retrofits - Impervious
DryPonds_puh	1,570	Mixed-Land Use SW Retrofits - Pervious
DryPonds_pul	1,775	Mixed-Land Use SW Retrofits - Pervious
EnhancedNM_nal	4,108	ENMPs
EnhancedNM_nhi	1,912	ENMPs
EnhancedNM_nho	4,360	ENMPs
EnhancedNM_nhy	51,183	ENMPs
EnhancedNM_nlo	75,612	ENMPs
ExtDryPonds_imh	248	Mixed-Land Use SW Retrofits - Impervious
ExtDryPonds_iml	150	Mixed-Land Use SW Retrofits - Impervious
ExtDryPonds_puh	829	Mixed-Land Use SW Retrofits - Pervious
ExtDryPonds_pul	657	Mixed-Land Use SW Retrofits - Pervious
Filter_imh	2,110	Mixed-Land Use SW Retrofits - Impervious
Filter_iml	11	Mixed-Land Use SW Retrofits - Impervious
Filter_puh	13,680	Mixed-Land Use SW Retrofits - Pervious
Filter_pul	43	Mixed-Land Use SW Retrofits - Pervious
ForestBuffersN_hom	43	Forrest Buffers
ForestBuffersN_hwm	1,122	Forrest Buffers
ForestBuffersN_hyw	2,110	Forrest Buffers
ForestBuffersN_pas	799	Forrest Buffers
ForestBuffersPS_hom	21	Forrest Buffers
ForestBuffersPS_hwm	1,122	Forrest Buffers
ForestBuffersPS_hyw	1,055	Forrest Buffers
ForestBuffersPS_pas	400	Forrest Buffers
ForestBufferstrpN_npa	27	Forrest Buffers
ForestBufferstrpN_pas	1	Forrest Buffers
ForestBufferstrpPS_npa	14	Forrest Buffers
ForestBufferstrpPS_pas	1	Forrest Buffers
ForestBufUrban_imh	900	Forrest Buffers
ForestBufUrban_iml	370	Forrest Buffers
ForestBufUrban_puh	4,029	Forrest Buffers
ForestBufUrban_pul	1,910	Forrest Buffers
ForHarvestBMP_for	0	N/A
ForHarvestBMP_hvf	14,681	N/A
GrassBuffersN_hom	300	Grass Buffers
GrassBuffersN_hwm	1,122	Grass Buffers
GrassBuffersN_npa	40	Grass Buffers
GrassBuffersN_pas	132	Grass Buffers

BMP Category Watershed Model Phase 5.3	Area Acres	BMP Category BMP Benefit Planner Version 1.1
GrassBuffersPS_hom	150	Grass Buffers
GrassBuffersPS_hwm	1,122	Grass Buffers
GrassBuffersPS_npa	20	Grass Buffers
GrassBuffersPS_pas	66	Grass Buffers
InfiltWithSV_imh	1,627	Ultra-Urban SW Retrofits
InfiltWithSV_iml	5	Ultra-Urban SW Retrofits
InfiltWithSV_puh	10,929	Ultra-Urban SW Retrofits
InfiltWithSV_pul	17	Ultra-Urban SW Retrofits
MortalityComp_afo	11	
PrecRotGrazing_npa	36,793	Rotational Grazing
UrbanNutMan_puh	47,018	NMPs
UrbanNutMan_pul	24,953	NMPs
WaterContStruc_hwm	105	Animal Waste Management
WetlandRestore_alf	0	Wetland Creation - Freshwater Mineral Soil - Conv Tillage
WetlandRestore_hom	21	Wetland Creation - Freshwater Mineral Soil - Conv Tillage
WetlandRestore_hwm	590	Wetland Creation - Freshwater Mineral Soil - Conv Tillage
WetlandRestore_hyw	31	Wetland Creation - Freshwater Mineral Soil - Conv Tillage
WetlandRestore_lwm	118	Wetland Creation - Freshwater Mineral Soil - Conv Tillage
WetlandRestore_pas	123	Wetland Creation - Freshwater Mineral Soil - Pasture
WetPondWetland_imh	875	Mixed-Land Use SW Retrofits - Impervious
WetPondWetland_iml	663	Mixed-Land Use SW Retrofits - Impervious
WetPondWetland_puh	3,001	Mixed-Land Use SW Retrofits - Pervious
WetPondWetland_pul	2,603	Mixed-Land Use SW Retrofits - Pervious
	590,950	

ATTACHEMENT B
***BMP Benefit Planner* Input Sheets**

BMP BENEFIT PLANNER INPUT

Scenario 1:	Default (Draft TMDL) Scenario
Description:	
York River Basin Draft TMDL	

Watershed Inputs

Total Watershed Area	3070	square miles
Total Watershed Stream-Miles		mi. (if known)
Watershed Stream Density	0.8	stream-miles/square mile

Total Flow Treated by Treatment Tier and WWTP Capacity Class

Nitrogen Removal					
Initial Effluent TN (mg/L)	**Target Effluent TN (mg/L)**	**WWTP Capacity Class S (<1 mgd)**	**M (1-10 mgd)**	**L (>10 mgd)**	**Units**
No N removal	8				Total MGD
No N removal	5				Total MGD
No N removal	3				Total MGD
8	5				Total MGD
8	3				Total MGD
5	3				Total MGD
CUSTOM Target Levels					
18.7	4	3.14	14	15	Total MGD
					Total MGD
					Total MGD

Phosphorus Removal					
Initial Effluent TP (mg/L)	**Target Effluent TP (mg/L)**	**WWTP Capacity Class S (<1 mgd)**	**M (1-10 mgd)**	**L (>10 mgd)**	**Units**
No P removal	1				Total MGD
No P removal	0.5				Total MGD
No P removal	0.1				Total MGD
1	0.5				Total MGD
1	0.1				Total MGD
0.5	0.1				Total MGD
CUSTOM Target Levels					
2.5	0.3	3.14	15	15	Total MGD
					Total MGD
					Total MGD

Scenario 1: Default (Draft TMDL) Scenario

Nutrient Management Planning

Conventional Fertilizer Application		
Conventional Fertilizer application rate	36	kg N/acre/year
Nutrient Management Plans		
Cropland & Hay under NMP	80361	acres
NMP Fertilizer application rate	29	kg N/acre/year
Enhanced Nutrient Management Plans		
Cropland & Hay under Enhanced NMP	137175	acres
Fertilizer application rate (Enhanced NMP)	26	kg N/acre/year

Conservation Tillage - Input

Initial Land Use			
Conventional Tillage	95017	acres	
Low Tillage	0.1	acres	
Managed Land Use			
Low Tillage	95017	acres	
No-Tillage	0.1	acres	

Initial land use is assumed to be 100% conventional tillage unless otherwise specified.

Cover Crops - Input

Area Newly Planted with Cover Crops	29062.3914	acres

Animal Waste Management - Input

Manure-Acres Treated	567.7387785	acres

Grazing Land Management (Rotational Grazing) - Input

Area Converted to Rotational Grazing	36792.96328	acres

Scenario 1: Default (Draft TMDL) Scenario

Riparian Buffers - Input

Forest Buffers		
Length of Buffer Planting	3032212	feet
Average Buffer Width	100	feet (default = 100 ft.)
Grass Buffers		
Length of Buffer Planting	642728	feet
Average Buffer Width	100	feet (default = 100 ft.)

Afforestation & Reforestation Area - Input

USMP Region	Afforestation: Cropland	Afforestation: Pasture	Reforestation	units
Appalachia/ N				acres
Appalachia/ P, S, and T				acres
Corn Belt/ L, M, N, O				acres
Corn Belt/ R				acres
Delta States				acres
Lake States				acres
Mountain States				acres
Northeast				acres
Northeast Plains				acres
Pacific States/ A and D				acres
Pacific States/ B, C, and E				acres
Southeast	0	0	0	acres
Southern Plains				acres

Wetland Creation/Restoration - Input

Freshwater Mineral-Soil (FWMS) Wetland		
Initial Land Use (Converted to FWMS wetland)		
Conventional Tillage	759.9288064	acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing	122.6675337	acres
Other (no initial fuel consumption)		acres
Forested Wetland		
Initial Land Use (Converted to Forested wetland)		
Conventional Tillage		acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing		acres
Other (no initial fuel consumption)		acres
Peatland		
Initial Land Use (Converted to Peatland)		
Conventional Tillage		acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing		acres
Other (no initial fuel consumption)		acres
Estuarine Wetland		
Initial Land Use (Converted to Estuarine wetland)		
Conventional Tillage		acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing		acres
Other (no initial fuel consumption)		acres

Scenario 1:	Default (Draft TMDL) Scenario

Stream Restoration - Input

Length of stream to be restored	0	feet

Stormwater Retrofits - Input

Mixed Land Use Retrofits		
Pervious Urban Land Treated	24450.73474	acres
Impervious Urban Land Treated	4842.751164	acres
Ultraurban Retrofits		
Total Land Treated	12577.8898	acres

BMP BENEFIT PLANNER INPUT

Scenario 2:	Alternative Scenario
Description:	
York River Alternative Scenario	

Watershed Inputs

Total Watershed Area	3070	square miles
Total Watershed Stream-Miles	0	mi. (if known)
Watershed Stream Density	0.8	stream-miles/square mile

Total Flow Treated by Treatment Tier and WWTP Capacity Class

Nitrogen Removal					
Initial Effluent TN (mg/L)	Target Effluent TN (mg/L)	WWTP Capacity Class S (<1 mgd)	M (1-10 mgd)	L (>10 mgd)	Units
No N removal	8				Total MGD
No N removal	5				Total MGD
No N removal	3				Total MGD
8	5				Total MGD
8	3				Total MGD
5	3				Total MGD
CUSTOM Target Levels					
18.7	6	3.14	14	15	Total MGD
					Total MGD
					Total MGD

Phosphorus Removal					
Initial Effluent TP (mg/L)	Target Effluent TP (mg/L)	WWTP Capacity Class S (<1 mgd)	M (1-10 mgd)	L (>10 mgd)	Units
No P removal	1				Total MGD
No P removal	0.5				Total MGD
No P removal	0.1				Total MGD
1	0.5				Total MGD
1	0.1				Total MGD
0.5	0.1				Total MGD
CUSTOM Target Levels					
2.5	0.7	3.14	15	15	Total MGD
					Total MGD
					Total MGD

Scenario 2: Alternative Scenario

Nutrient Management Planning

Conventional Fertilizer Application		
Conventional Fertilizer application rate	36	kg N/acre/year
Nutrient Management Plans		
Cropland & Hay under NMP	96433.2	acres
NMP Fertilizer application rate	29	kg N/acre/year
Enhanced Nutrient Management Plans		
Cropland & Hay under Enhanced NMP	164610	acres
Fertilizer application rate (Enhanced NMP)	26	kg N/acre/year

Conservation Tillage - Input

Initial Land Use			
Conventional Tillage	95017	acres	
Low Tillage	0.1	acres	
Managed Land Use			
Low Tillage	114020.4	acres	
No-Tillage	0.1	acres	

Initial land use is assumed to be 100% conventional tillage unless otherwise specified.

Cover Crops - Input

Area Newly Planted with Cover Crops	34874.86968	acres

Animal Waste Management - Input

Manure-Acres Treated	681.2865342	acres

Grazing Land Management (Rotational Grazing) - Input

Area Converted to Rotational Grazing	44151.55594	acres

Scenario 2: Alternative Scenario

Riparian Buffers - Input

Forest Buffers		
Length of Buffer Planting	3638654.4	feet
Average Buffer Width	100	feet (default = 100 ft.)
Grass Buffers		
Length of Buffer Planting	771273.6	feet
Average Buffer Width	100	feet (default = 100 ft.)

Afforestation & Reforestation Area - Input

USMP Region	Afforestation: Cropland	Afforestation: Pasture	Reforestation	units
Appalachia/ N				acres
Appalachia/ P, S, and T				acres
Corn Belt/ L, M, N, O				acres
Corn Belt/ R				acres
Delta States				acres
Lake States				acres
Mountain States				acres
Northeast				acres
Northeast Plains				acres
Pacific States/ A and D				acres
Pacific States/ B, C, and E				acres
Southeast	0	0	0	acres
Southern Plains				acres

Wetland Creation/Restoration - Input

Freshwater Mineral-Soil (FWMS) Wetland		
Initial Land Use (Converted to FWMS wetland)		
Conventional Tillage	911.9145677	acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing	147.2010404	acres
Other (no initial fuel consumption)		acres
Forested Wetland		
Initial Land Use (Converted to Forested wetland)		
Conventional Tillage		acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing		acres
Other (no initial fuel consumption)		acres
Peatland		
Initial Land Use (Converted to Peatland)		
Conventional Tillage		acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing		acres
Other (no initial fuel consumption)		acres
Estuarine Wetland		
Initial Land Use (Converted to Estuarine wetland)		
Conventional Tillage		acres
Mulch- & Ridge-Tillage		acres
No-Tillage		acres
Conventional Grazing		acres
Rotational Grazing		acres
Other (no initial fuel consumption)		acres

Scenario 2:	Alternative Scenario

Stream Restoration - Input

Length of stream to be restored	0	feet

Stormwater Retrofits - Input

Mixed Land Use Retrofits		
Pervious Urban Land Treated	12225.36737	acres
Impervious Urban Land Treated	2421.375582	acres
Ultraurban Retrofits		
Total Land Treated	6288.9449	acres

ATTACHEMENT C
***BMP Benefit Planner* Output Sheets**

BMP Benefit Planner TABULAR RESULTS

Input Summary	Scenario 1	Scenario 2
Total Flow Treated for N-Removal (MGD)	32.14	32.14
Total Flow Treated for P-Removal (MGD)	33.14	33.14
Nutrient Management Planning Implemented (acres)	80,361	96,433
Low-Tillage (acres)	95,017	114,020
No-Tillage (acres)	0	0
Area Newly Planted with Cover Crops (acres)	29,062	34,875
New Animal Waste Management Practices (manure-acres)	568	681
Area Converted to Rotational Grazing (acres)	36,793	44,152

Input Summary	Scenario 1	Scenario 2
Forest Buffers Planted (acres)	13,922	16,706
Grass Buffers Planted (acres)	2,951	3,541
Total Area of Forestation (acres)	0	0
Total Area of Wetlands Created/Restored (acres)	883	1,059
Feet of Stream to be Restored	0	0
Area Served by New Retention/Detention Basins (acres)	29,293	14,647
Area Served by New Bioretention/Biofiltration (acres)	12,578	6,289

SCENARIO 1: Default (Draft TMDL) Scenario

Output Summary	TOTAL	WWTP Nut. Rem. Upgrade	Nutrient Management Planning	Conservation Tillage	Cover Crops	Animal Waste Management	Rotational Grazing	Riparian Buffers	Afforestation and Reforestation	Wetland Restoration	Stream Restoration	Stormwater Retrofits
Capital Cost ($)	$2,026,468,409	$143,009,299	$5,066,645	$0	$0	$24,635,591	$6,765,373	$22,390,535	$0	$1,321,032	$0	$1,823,279,934
O&M Cost ($/year)	$62,579,481	$7,870,372	$0	$316,815	$961,902	$2,009,682	$270,615	$0	$0	$41,175	$0	$51,108,920
Annualized Total Cost ($/year)	$228,443,135	$19,345,808	$1,860,515	$316,815	$961,902	$5,653,981	$1,146,762	$1,616,622	$0	$127,110	$0	$197,413,620
GHG Emissions (Mg CO2e/yr)	-2.3E+03	2.3E+04	-2.4E+04	-1.2E+03	2.1E+02	0.0E+00	-1.2E+03	0.0E+00	0.0E+00	5.2E+02	0.0E+00	0.0E+00
Carbon Sequestration Rate (Mg CO2e/yr)	8.1E+04	0.0E+00	0.0E+00	4.9E+04	8.5E+03	0.0E+00	4.4E+03	1.9E+04	0.0E+00	1.2E+02	0.0E+00	3.1E+02
Lifetime Carbon Sequestration Potential (Mg CO2e)	7.3E+06	0.0E+00	0.0E+00	9.8E+05	1.7E+05	0.0E+00	8.7E+04	6.1E+06	0.0E+00	2.2E+04	0.0E+00	2.3E+04
Cost per Pound Nitrogen Reduced ($/lb/yr)	$51.92	$7.42	$1.65	$1.62	$5.85	$5.92	$16.26	$6.84	–	$2.48	–	$1,238.76
Cost per Pound Phosphorus Reduced ($/lb/yr)	$342.17	$39.11	$10.29	$5.00	$155.98	$48.69	$80.31	$142.03	–	$10.32	–	$4,791.97
Cost per Ton Sediment Reduced ($/ton/yr)	$4,429.84	–	–	$9.43	$280.92	–	$293.45	$347.58	–	$91.32	–	$42,824.98

Other Ancillary Benefit Summary	Scenario Average	WWTP Nut. Rem. Upgrade	Nutrient Management Planning	Conservation Tillage	Cover Crops	Animal Waste Management	Rotational Grazing	Riparian Buffers	Afforestation and Reforestation	Wetland Restoration	Stream Restoration	Stormwater Retrofits
Wildlife (terrestrial or wetland) habitat	3.2	0.0	0.0	1.2	0.4	0.0	0.9	0.1	0.0	0.0	0.0	0.5
In-stream (aquatic) habitat	7.0	0.0	0.0	3.6	0.7	0.0	0.9	0.1	0.0	0.0	0.0	1.6
Aesthetics	2.9	0.0	0.0	1.2	0.4	0.0	0.5	0.1	0.0	0.0	0.0	0.7
Public health	4.3	0.0	2.8	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.5
Flood hazard mitigation	7.5	0.0	0.0	4.8	1.1	0.0	0.0	0.1	0.0	0.0	0.0	1.4
Groundwater recharge and baseflow protection	5.1	0.0	0.0	3.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7

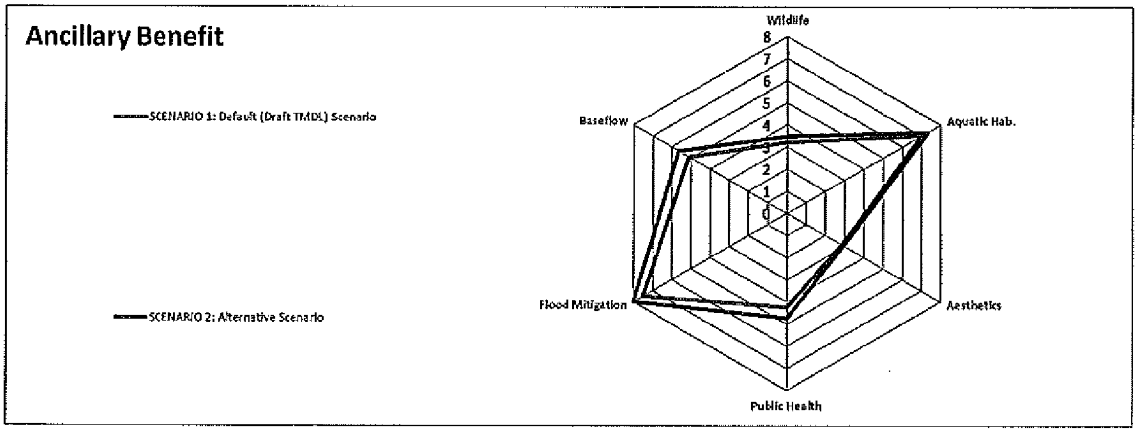
BMP Benefit Planner TABULAR RESULTS

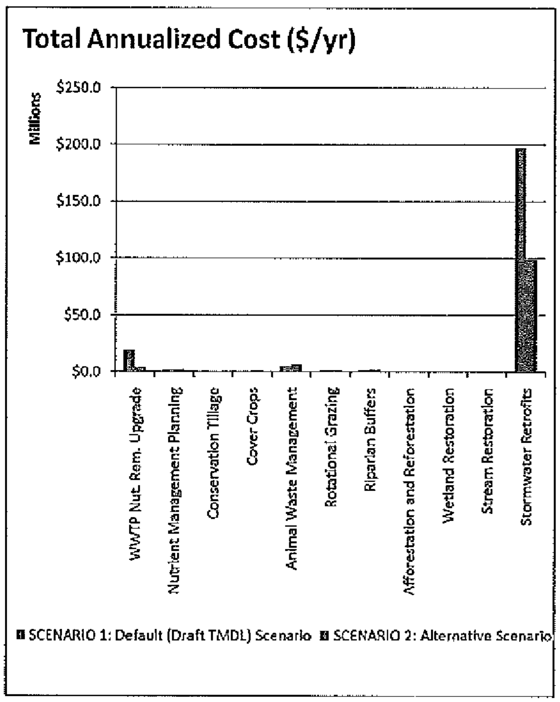
SCENARIO 2: Alternative Scenario

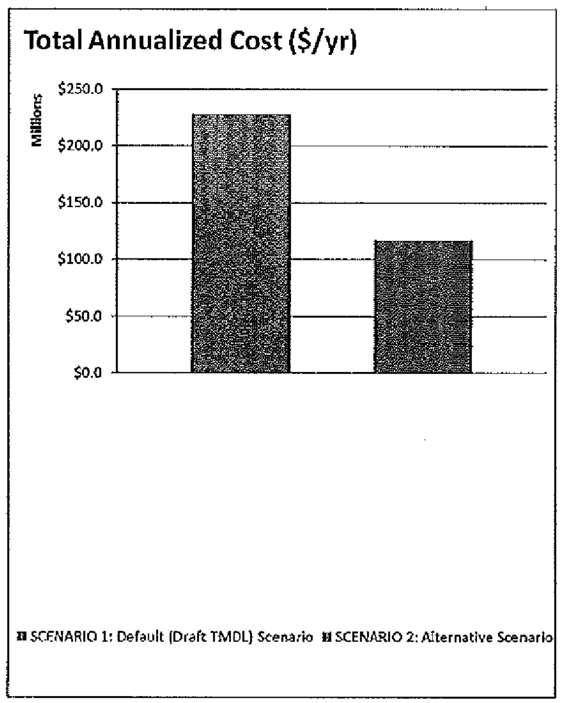
Output Summary	TOTAL	WWTP Nut. Rem. Upgrade	Nutrient Management Planning	Conservation Tillage	Cover Crops	Animal Waste Management	Rotational Grazing	Riparian Buffers	Afforestation and Reforestation	Wetland Restoration	Stream Restoration	Stormwater Retrofits
Capital Cost ($)	$1,027,823,507	$43,968,528	$6,079,974	$0	$0	$29,562,709	$8,118,447	$26,868,642	$0	$1,585,239	$0	$911,639,967
O&M Cost ($/year)	$30,577,153	$702,466	$0	$380,178	$1,154,282	$2,411,618	$324,738	$0	$0	$49,410	$0	$25,554,460
Annualized Total Cost ($/year)	$116,957,873	$4,230,615	$2,232,618	$380,178	$1,154,282	$6,784,777	$1,376,114	$1,939,947	$0	$152,532	$0	$98,706,810
GHG Emissions (Mg CO2e/yr)	-1.9E+04	1.2E+04	-2.8E+04	-1.4E+03	2.5E+02	0.0E+00	-1.4E+03	0.0E+00	0.0E+00	6.2E+02	0.0E+00	0.0E+00
Carbon Sequestration Rate (Mg CO2e/yr)	9.7E+04	0.0E+00	0.0E+00	5.9E+04	1.0E+04	0.0E+00	5.2E+03	2.3E+04	0.0E+00	1.5E+02	0.0E+00	1.6E+02
Lifetime Carbon Sequestration Potential (Mg CO2e)	8.8E+06	0.0E+00	0.0E+00	1.2E+06	1.7E+05	0.0E+00	1.0E+05	7.3E+06	0.0E+00	2.2E+04	0.0E+00	1.2E+04
Cost per Pound Nitrogen Reduced ($/lb/yr)	$24.96	$3.08	$1.65	$1.62	$5.85	$5.92	$16.26	$6.84	--	$2.48	--	$1,238.76
Cost per Pound Phosphorus Reduced ($/lb/yr)	$170.10	$2.24	$10.29	$5.00	$155.98	$48.69	$80.31	$142.03	--	$10.32	--	$4,791.97
Cost per Ton Sediment Reduced ($/ton/yr)	$1,993.96	--	--	$9.43	$280.92	--	$293.45	$347.58	--	$91.32	--	$42,824.98

Other Ancillary Benefit Summary	Scenario Average	WWTP Nut. Rem. Upgrade	Nutrient Management Planning	Conservation Tillage	Cover Crops	Animal Waste Management	Rotational Grazing	Riparian Buffers	Afforestation and Reforestation	Wetland Restoration	Stream Restoration	Stormwater Retrofits
Wildlife (terrestrial or wetland) habitat	3.5	0.0	0.0	1.5	0.4	0.0	1.1	0.1	0.0	0.0	0.0	0.3
In-stream (aquatic) habitat	7.3	0.0	0.0	4.4	0.9	0.0	1.1	0.1	0.0	0.0	0.0	0.8
Aesthetics	2.9	0.0	0.0	1.5	0.4	0.0	0.6	0.1	0.0	0.0	0.0	0.3
Public health	4.7	0.0	3.3	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.3
Flood hazard mitigation	8.0	0.0	0.0	5.8	1.3	0.0	0.0	0.1	0.0	0.0	0.0	0.7
Groundwater recharge and baseflow protection	5.6	0.0	0.0	4.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3

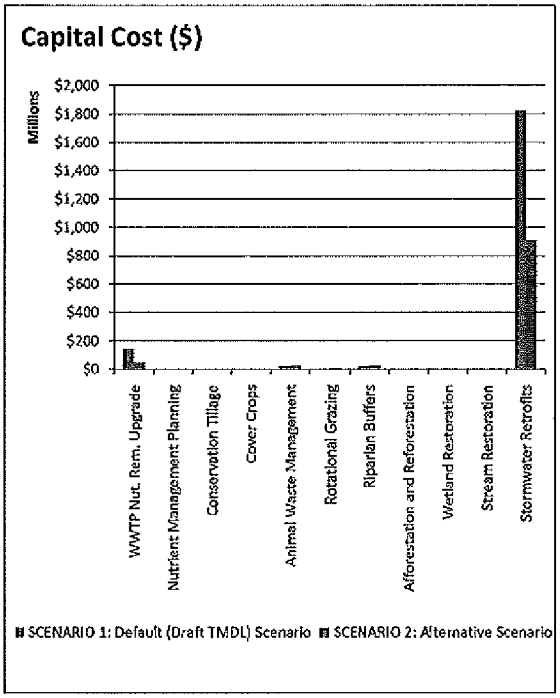
BMP Benefit Planner GRAPHICAL RESULTS

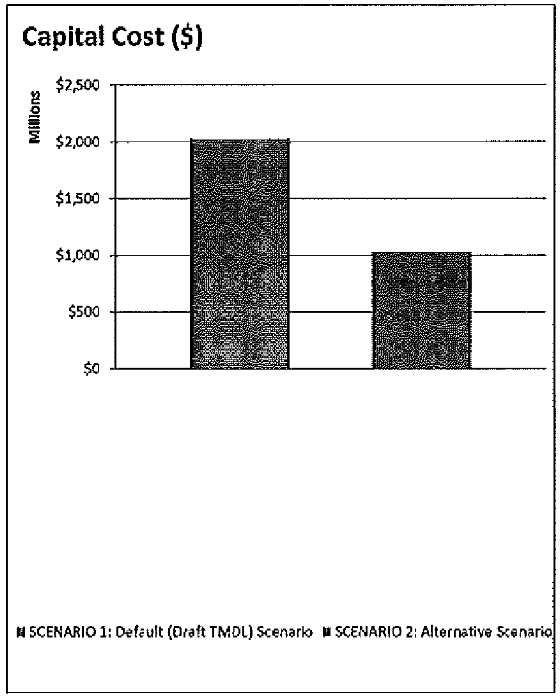


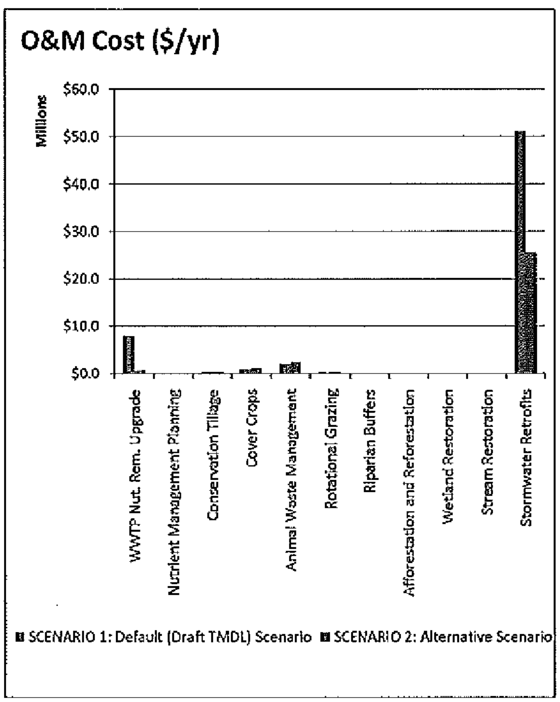


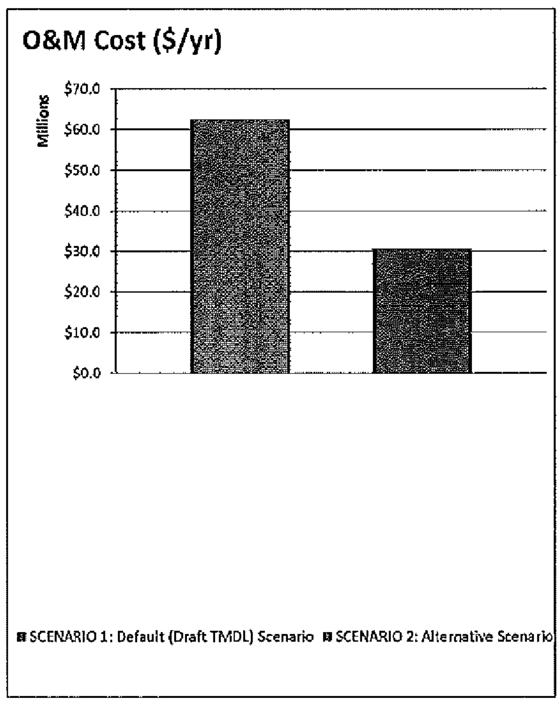


BMP Benefit Planner GRAPHICAL RESULTS









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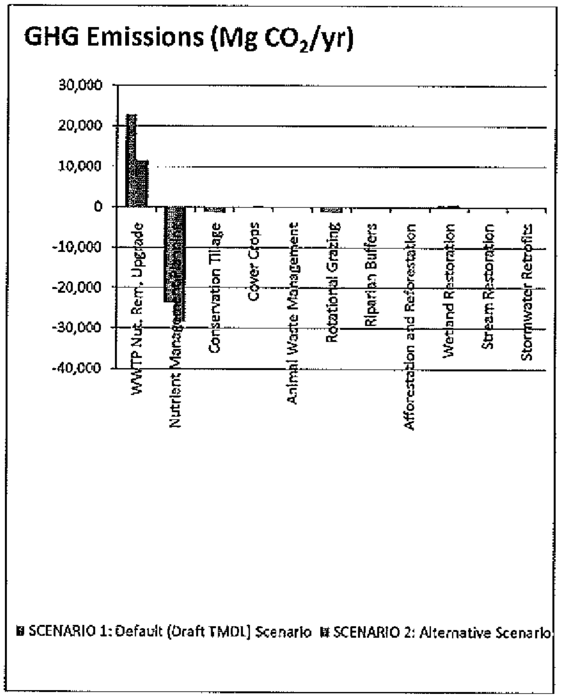

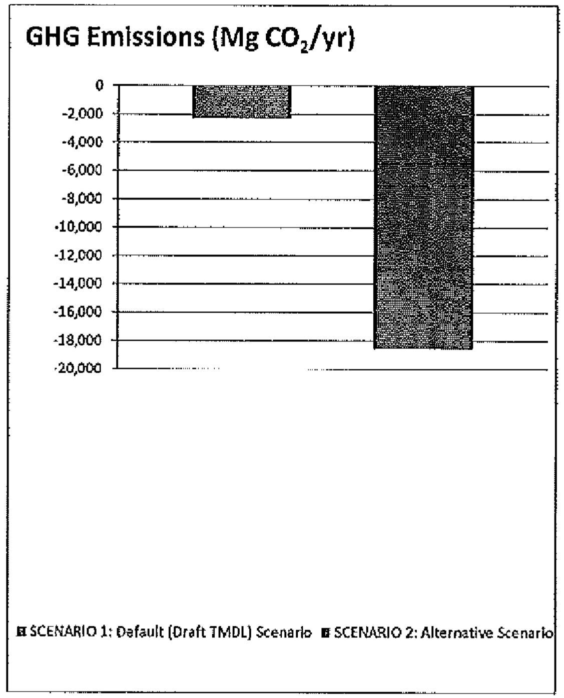

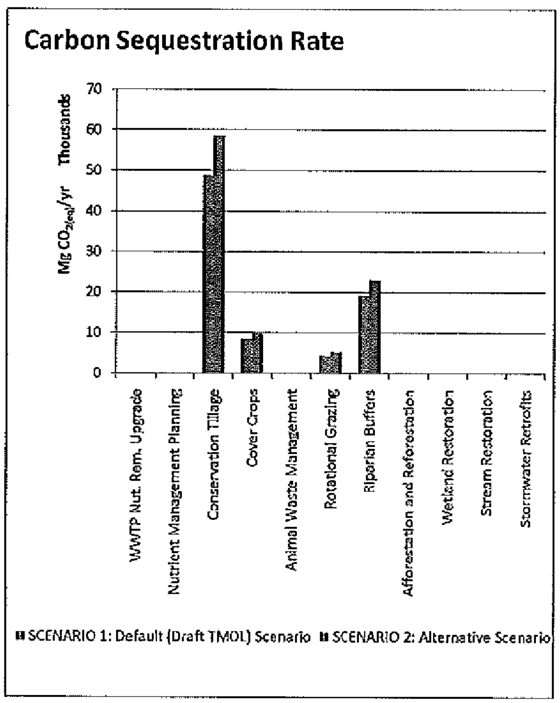

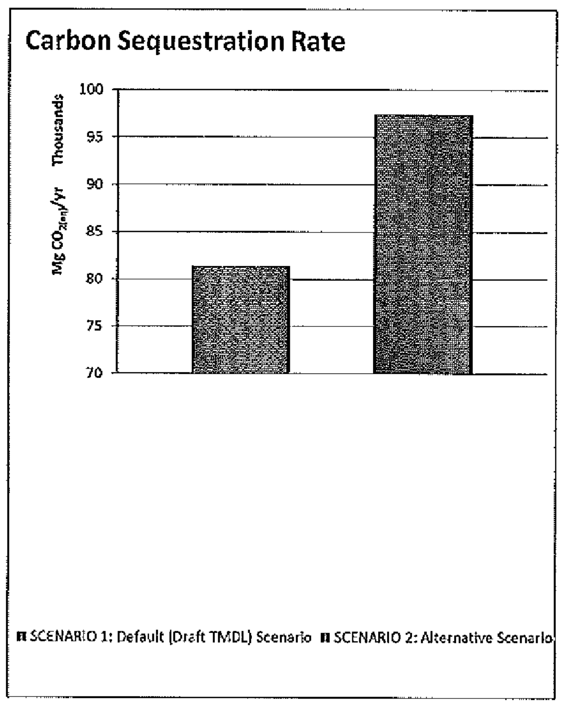

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